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AN ECOLOGICAL MODEL FOR THE PROCESSING OF SYMBOLIC INFORMATION[1]

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Summary.—This article points out that an adequate cognition-oriented approach to the processing of symbolic information abstracted from verbal expressions must consider running text instead of scattered sentences. It is argued that the dominant cognition models do not give due consideration to the fact that a valid abstraction of information structures has to be based on an explicit encoding of intentionality and valuation. A model must cope with empirical context and novelty instead of truth-values in semantic-logical contexts. The proposed theory has been tested empirically on text material considered to be anamorphic. Its underlying key relations can be extracted by means of discriminant functions and given a meaningful interpretation.

The study of cognition requires methods and techniques for an abstraction of information from verbally expressed experiences. When people can express themselves verbally, i.e., freely and unrestrictedly, it becomes possible to get access to information of high validity regarding the intentionality and valuation of people's experiences, which form their cognitive structure. Since mathematical and other logical expressions are restricted in kind, I will disregard such non-natural languages when referring to human information-processing (cognition).

The analytical problem of making inferences from verbal expressions is much the same as with other types of data. Specific events, behaviors, or qualities characterizing certain objects and events have to be inferred. Thus, the process of inference making requires that relationships between events and verbally reported experiences can be established.

The immaterial character of the concept of information is further emphasized through the integration of computers in the technically advanced societies. "Data flow" and "transformation of information" are descriptive, although abstract concepts, labelling processes whose operation is difficult for people

[1]This article is based on many key ideas and studies which have been developed within several research programmes financed by the National Board of Education, Sweden. These programmes would not have come into existence without its support. Within these programmes many people have worked together to make a systematic study of symbolic information in anamorphic text approachable. First of all, I express my gratitude to my fellow researchers who without reservation have served as experimental subjects. It is a pleasure for me to convey my appreciation to Dr. Inger Bierschenk for her discerning contributions in making an extensive text accessible to computer-based analyses. My gratitude also is extended to the research students and research assistants who over the years participated in certain phases of the programmes. In this connection, I thank especially M.-L. Annerblom, B.A. and M. Berg, B.A. I thank particularly L. Robertson, B.A. and A. Sternerup-Hansson, B.A., for contributions to the development of several computer programmes and for carrying out the analysis.
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outside the programmers' circle to conceive. The development of electronic "information-processing machines" has started a new phase by the abstraction of information from symbols. At the same time one may ask whether, and the extent to which, information from psychological phenomena, such as the structure of human intelligence, can be abstracted and represented symbolically through the logical formalism that gives the basis of computer technology, i.e., the structure of artificial intelligence.

The analogy made between man and the machine may mainly be referred to the fact that they are advanced symbol handling devices. Symbols may be considered as holding abstracted information. But the ability to abstract information from a string of symbols presupposes not only a device that has been provided with the capacity to "retrieve" a string of symbols, e.g., a verbal expression, but also that there has to be means of "storing of context." Without access to context, symbols cannot be recognized and used in the processing of symbolic information, since the risk of misuse is too obvious. An adequate cognition-oriented approach to symbol information processing must consider running text, thus providing methods and techniques for making inferences to relationships between symbols, e.g., relationships expressing typically human experiences provided in a typically human manner.

The emphasis in this article is placed on a theoretical discussion and the empirical study of information structures contained in anamorphic text as opposed to well-formed but scattered sentences cited by generations of philosophers, linguists, and psychologists. The study of anamorphic text requires not only a model that takes into account the linguistic context of sentence relations, but also the structural properties of a text as a whole. From a cognitive point of view, information derived from symbols could not easily be separated from the human context, which implies that the information-processing model should also consider the experiences characterizing the producers of the text. Thus, the empirical or social context becomes important.

When inferences are to be drawn from an analysis of empirical context, the model is interactive in the sense that it builds on the dynamics of the different contextual levels. I will call such a model *ecological*. Furthermore, when humans produce a text verbally, especially spoken language, their anamorphic structuring of the empirical context requires certain techniques for the organization of information and the processing of symbols at several levels simultaneously. In short, an ecological model for the processing of symbolic information both requires and provides continuous changes of perspective.

An Ecologically Based Model of Cognition

The model to be presented here is based on the assumption that human cognition does not follow the same strict formalism as that of electronic information-processing machines. The ecological perspective of the psychological approach taken stresses the fact that humans ordinarily can recognize objects and events in their environment with absolute certainty. However, when it comes to the construction of a model of human information processing, cognition-oriented scientists and some quarters in cognitive psychology stress the formal logical approach, assuming that humans, like computers, function in a formal-logical way, i.e., they behave according to the phenomenon described as "expectation" or "hypothesis."

Within the framework of human cognition two general hypotheses can be discerned, namely (1) the frame hypothesis and (2) the schema hypothesis (see B. Bierschenk, 1981). The first assumes that perceptual constancy has to be established before any account of cognition (symbolic information processing) can be given. This is the approach taken by the Gestalt psychologists, which has been further developed for computer simulation (Winston, 1975). In works within artificial intelligence (AI) the classical bases of "size," "distance," and "form" underlies, e.g., the restricted knowledge world of blocks in Winograd (1972) and the development of stereotyped verbal scenarios, called scripts, as in Schank and Abelson (1977).

The second hypothesis has advantages with respect to the completeness of the information to be processed, i.e., the preciseness of the cognition of objects and events can vary widely. Thus, a model constructed according to this hypothesis would consider Gibson's (1966, 1979) view of "formless invariants over time" as a basic assumption. Jenkins (1977) assumes that cognitive structures develop as a result of "progressive actions" within a structurally defined context. It can, therefore, be proposed that cognition changes continuously but structural invariants can be detected.

A model capable of representing human information processing expressed verbally has to incorporate devices for the transformation and structural change. There are several models in use, at least for the purpose of simulating understanding of natural language text. From an input string consisting of "words" it is a question of building up concepts. Linguistically based models, e.g., of the S v O (syntactical) or N_1 v N_2 (semantical, predicate-argument) type are suitable for constructing grammatical relationships and lexical specifications for the processing of a formal knowledge of the world. Whether in the form of primitive feature matching for building up semantic networks (Quillian, 1968), ATN grammars for answering questions within a well-defined field (Woods, 1973), Conceptual Dependency structuring for inference making in story telling (Schank, 1972; Schank & Abelson, 1977), or hierarchical structuring of topics (Schubert, *et al.*, 1976) for determination of knowledge concepts, adaptation of such a model builds on an assumption that our knowledge is a network of facts, inherent in a pre-programmed "meaning" of words and groups of words, whose relationships can be defined by a formal-logical adaptation of truth-value pairs. A model similar to the schema

is the template structure elaborated by Wilks (1973) for machine translation. However, the over-all components represent pure logic, thus being adapted to computer intelligence in the transformation strategy.

A way of approaching a verbal expression with respect to its symbolic nature is represented by the Agent-action-Object(ive) (A a O) model. According to Werner and Kaplan (1963), the A a O model is used for

". . . counting states of affairs and articulating them linguistically to formulate attributive propositions about conceptual relations in terms of that action model" (p. 57).

Instead of relying on "expectation" and "hypothesis," this model can be utilized in formalizing "integration" and "unconditional judgment." This means that symbolic information (cognition represented by concepts) cannot be reconstructed from individual words only. The directiveness, characteristic of purposeful behavior, and the degree of variability (perspective) together represent the adaptability, the coping with novelty that is a necessary device for the construction of symbols. This process involves empirical judgment, i.e., an integration or a dynamic interaction between the values established, the actions performed (events), and the intentions behind the perspective chosen.

Intentionality and Valuation

Organizational variables account for the richness of variation in the manifestation of one and the same conceptualization in various verbal expressions. Moreover, these are characterized by certain parts being mobile, while others have fixed positions. Conceptualizations may be manifest in simple or more complex patterns of expression. Thus, an expression consists of syntactic units, which means that the syntactic position of a word can alter its informative value. The position of a unit is to be regarded as the manifestation of a viewpoint in language form.

The Agent component in the A a O model is used in the sense of "action centre." Consequently, certain events are regarded as instigated by something, including natural forces, i.e., the laws of nature (see Bierschenk & Bierschenk, 1976). Since the A a O model is an action schema, it is important to consider the whole model, i.e., the verbal manifestation of the agent's coincidences with the object(ive) and the reverse. To establish such coincidences an encoding system has been developed (I. Bierschenk, 1977), which specifies each concept by a two-figure code. A a O is expressed as 30 + 40 + 50. The direction of the action is under control in such a way that, e.g., a 50 + 40 + 30 figuration would represent a "by-clause." The coincidences between the As and the Os are to be determined by the verb linkage. In the model, this phenomenon has been called *intentionality*. It builds on the assumption that there exists a symmetrical relationship between the agents and the objects, and consequently, the same basic constructional properties can be presumed in both agent and object. One example:

I called our new librarian [1a]
30 40 51 52 50
Our new librarian called me [1b]
31 32 30 40 50

The two-figure codes not ending with zeros denote the extensional dimension.

Like the fact-based models, this coding system can build up and store descriptive attributes about the nouns. In addition, it can keep apart attributes of importance to a certain noun in agent and in object function, respectively. A basic difference, however, between the A a O model as it is employed here, and a model with linguistically based variables is the functionally oriented view of activation. An example in connection with [1] above is:

Our department usually gets relevant information from the library [2]

An "A a O"-based coding of this expression sees the library as having the agent function. "Ecologically" seen, a library may act, i.e., the people of the organization are implicit. Another perspective may be taken when library is processed as having objective function, implying the objects within the organization (book-shelves, etc.). Thus, psychological facts differ from logical. This property of the model provides for the making up of empirically based information structures. The other is the treatment of the central role of the verbs. Like fact-based models, not any verb can link any nouns. But unlike the fact-based models, this model assumes a value structure, a result of personal choice, underlying the conceptual manifestation, i.e., the verbal processing of a certain piece of information. It can be argued that humans define themselves and others through their actions, therefore the human processing of environmental information necessarily integrates their *valuation* of both the actions and the agent-objective pairs involved. The perspective chosen of each A a O processed can be regarded as the individual processor's intentional strategy.

The processing of ecological information is a processing of meaning. Thus, meaning implies the existence of some kind of dimensionality. A method often used for studying dimensionality in meaning is Osgood's Semantic Differentials. Osgood (1969) claims that the established three scale dimensions "Evaluation" (E), "Activity" (A), and "Potency" (P), or dominance, are in fundamental agreement with Wundt's (1918) three ways of classifying value. The highest loading pairs of adjectives are: Positive—Negative equals Pleasure—Listlessness; Active—Passive equals Stress—Detachment; Strong—Weak equals Excitement—Calming. Semantic differentials have usually been used to describe the dimensionality of a certain noun by a set of adjectives. The approach taken in this experiment is to establish values (scaling) of the *verbs* out of context. The context-free assessment circumvents the problem that the semantic structure in the selected adjective scales changes as a function of the noun to be assessed.

Nouns combined with their respective verb within a certain expression

constitute a concept. The assessment of dimensionality (P,A,S) in the verb provides the processing of empirical meaning of each concept. If, for example, the social context is a university department, the person processing the information is a visiting professor, and the text produced is the professor's conceptualizations of his activities there, some of his verbal expressions could be:

I often have contacts with the librarian, and [3]
(I have) also (contacts) with my colleagues, and [4]
sometimes I discuss with the graduate students [5]

If it could be assumed that this professor's valuation of the verbs "have contact" and "discuss" on a 7-point bipolar scale had resulted in the dimensions

	P	A	S
have contact	4	4	4
discuss	5	6	5

then the interpretation of his conceptualization would be the following: the activities with both the library and the colleagues are not as active or intense as those with the students, although they are more frequent (the adverbs). Since the professor evaluates having contacts lower than discussing, the empirical information could be that he would appreciate meeting the students more frequently. However, the interpretation would require more information about the person's conceptualization of the concepts involved. He might convey different viewpoints as the text continues. Such an anamorphic structuring presupposes an analysis technique for finding the informative parts.

Several information-processing experiments show that humans construct conceptual schemas (Jenkins, 1977; Kintsch, 1974). In recognition, e.g., of events presented in sentence form, an over-all conceptualization seems to be recognized, i.e., the relation holding between Agents and Objects, irrespective of the verb. This means that the function of the verb is to establish the connection. When this has been done, its own dimensionality is incorporated in the respective nouns, making up the conceptual structure. In this experiment, this function has been employed in using the valuation of the verb as the linkage device of a matrix, in which the intentionality is expressed in the form of the agents on the y-axes and the objects on the x-axes. The coincidences of verbs and objects construct the concepts while the values assigned determine the empirical information. The examples [3] and [4] above generate a "contact cluster" because "contact" connects both "library" and "colleagues" with the agent (Professor X). Thus "empirical facts" about him have been established. He conceptualizes library contacts and collegial contacts as having the same properties (values). All the information processed by Professor X can be analyzed to construct an over-all schema of his conceptualization of a certain environment. His colleagues may process their schemas of that environment, which makes it possible to detect the structural invariants

for groups. This presupposes knowledge of common values of the group and imposes perspective.

Population and Material

The field, or context, is social science research. The representatives of the field are researchers, including psychologists, educationists, and sociologists. After "researcher" had been defined, a strictly random sample was drawn (32%) from the resulting population ($N = 126$).

The environment of the researchers, i.e., the ecological setting for the information processing, is their grant-supported research. The perspective imposed by the experiment is the question of information-search strategies associated with formulation of the problem, assumed to be basic for the following strategies. Researchers have produced answers to four questions:

1. In which way have you tried to gain more detailed complementary knowledge?
2. How consistently during the formulation process have you made use of channels of information such as libraries, etc.?
3. What type of information have you searched for and which search strategy have you used?
4. Could you say anything about how one should design information searching to create ideal conditions for the research process? Have you any suggestions for improvement?

An investigatory strategy suitable for an analysis of so-called ill-defined problems is represented by the interview method. The strategy taken here has provided for the researchers' free and uncommitted comments on the problem area, which implies the processing of symbolic information of high validity, although organized within an extremely anamorphic textual composition. Recognizing the researchers' cognition is to find the informative parts being distributed throughout the whole text material. When a certain passage of text has to be processed (analyzed) all the cues to the information necessary for the conceptualization to be formed may not be present. Text produced in free interviews may reflect a person's change of view.

The text has been manually encoded according to the ANACONDA (Analysis of Concepts by Data Processing) system (I. Bierschenk, 1977). After encoding of the intentional and extensional structure of the text, and making supplements according to linguistic context for making the A a O relationships manifest, textual units (ca 35,000) were transferred to IBM cards.

Empirical Procedure

Establishment of Common Value

It is assumed that the researcher's observations concerning himself and his environment are validly reflected by his verbal expressions. Therefore, it should be possible to distinguish informative from non-informative parts in anamorphic text. On the other hand, language is considered to be a product of conventional agreement. This implies that each of a multitude of aspects may exert a significant influence on the informative value of certain parts of

a verbal expression. If an expression is informative, this should be manifest in a value structure that is invariant while perspectives change.

To represent different perspectives a panel of 15 randomly selected researchers from the population defined (see p. 669) was set up to assess the values of the verbs. With the purpose of studying the dimensionality in the value structure represented by the verbs, a reduced component analysis was carried out. The method assumes that the values a judge assigns any one of the verbs are not determined by only one source of variation, i.e., one perspective, but by several. Thus, if the 15 judges of the panel basically value the verbs in the same way, this should give rise to one common component. However, emergence of two or more components would imply that different perspectives exist, depending on how the judges have weighted on each dimension. Here it will suffice to state that the valuation has given rise to one common component in each set of scores. About 800 verbs were scored by means of an interval ranging from 1 to 7. The maximal reliability of the value has been calculated from the largest characteristic root of the correlation matrix. The estimations for the E-, A-, and P-scaled dimension are $a_{\max} = .95, .93, .86$, respectively.

Identification of Symbolic Information

The main goal has been to transform an anamorphic text to a consistent informational structure, i.e., a metamorphic structure. The cluster analysis technique was chosen. An interactive application of the clustering technique condensed this heterogeneous material considerably. The measurement used for the association between A-O pairs is "Euclidean distance." This distance is defined as "the square root of the sum of the squared differences between the values for pairs of variables." The amalgamation algorithm used in the analysis is "the average linkage algorithm." The rule states that the mean distance is to be calculated between a variable in the first group formed and a variable in the second. The similarity coefficients have then been transformed into product-moment correlations. The values of similarity coefficients can vary between 1.00 (perfect agreement) and .00 (no agreement at all). The lowest limit used to merge variables into a cluster formation is a similarity value of .30 expressed as a product-moment correlation. The summary of the agent structure shows two main clusters, namely, "Information Dissemination" (Literature, Symposium, etc.), and "Methodology Oriented Researcher." Referring to the definition of Agent as action instigator and the functional properties of the model, this result seems relevant against the perspective chosen. Object(ive) clusters are the goal-oriented, abstract "Discussion of Problems" (Problem, Discussion), and the concrete "Channels of Information" (Symposium, Departmental Library, Psychological Abstracts, etc.). It should be noted that, e.g., Symposium has two functions in this environment.

The coding of intentionality as a property of a clause is central for matrix manipulation of the components in the A a O model. By linking the assessed values of the action components with the Object(ive) cluster, each cluster is provided with information values and, the matrix so formed allows estimation of dimensionality in symbolic information structures.

Construction of an Empirical Schema

In a multivariate study, by means of a discriminant analysis, the interaction between concepts and their scaled values can be used as a basis for the identification of the structure characterizing symbolic information as defined by discriminant functions.

A discriminant analysis procedure has been carried out resulting in the discriminant functions graphically presented in Fig. 1, together with their standardized coefficients. (For detailed numerical information and description, the reader is referred to B. Bierschenk, 1977a). The process starts with the coded text according to the A a O model from which A-O pairs are extracted on the basis of their coincidences as defined by the verb connecting them. Thereafter the process proceeds with the described cluster analysis. The derived clusters define the score matrix ($p \times N$), that contains the values that the verbs have assumed through the scaling procedure. The concepts represent the predictor variables, i.e., six concept clusters ($p = 6$), while N stands for the total sample size ($N = 42$) comprising the three groups formed on the basis of the scaled value dimensions (E, A, P). From this a correlation matrix ($p \times p$) is then computed.

From the computed correlation matrix two $p \times p$ matrices can be constructed, where the first one expresses the within-group variance (W), while the other gives the between-group variance (B). On the basis of the within- and the between-groups' variances or correlations, eigenvalues are computed ($\lambda = W^{-1}B$). This expression indicates the discriminating power in the values as expressed by the corresponding linear combination of the values (Tatsuoka, 1971).

The process of arriving at the first eigenvector value is pictured by the matrix equation ($D = ZA$), which provides a set of weights such that the resulting linear combination has the largest possible discriminant criterion. The three groups of scaled values pictured allow for two eigenvectors. The linear combinations of the informative values as presented by both functions have been formed to maximize the variance between the three groups of values compared to the variance within the groups. In this scheme, the interaction between values and concepts gives a basis for estimation of error variance.

Fig. 1 clearly shows that two discriminant functions have been formed by the program used (Nie, *et al.*, 1975). The first function is the most important one for a discrimination of the values, as defined by the E—, A—,

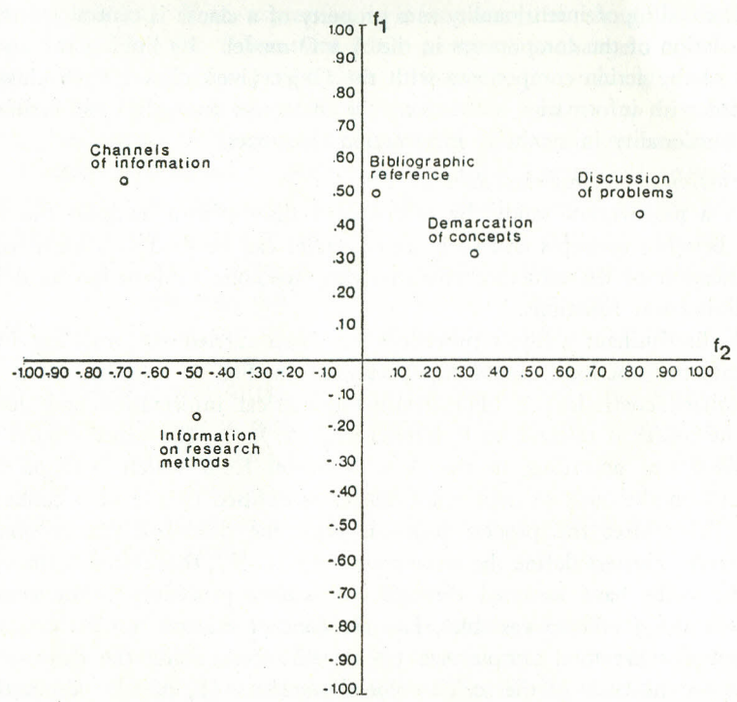

FIG. 1. Discriminant functions (I, II) and their standardized coefficients

and P— scale. This function is most heavily loaded by the concept clusters "Bibliographic Reference" and "Channels of Information." On the other hand, the second one shows a high negative weight on the second function. The second function is needed to differentiate the values with respect to the concept clusters "Discussion of Problems" and "Information on Research Methods," while the values pertaining to the concept cluster "Demarcation of Concepts" seem to be equally important for both functions.

A contextual interpretation is given in the following discussion.

The interpretation of the discriminant analysis may be conceived within the framework of additional information gathered by means of a separately administered measurement instrument containing scaled statements on the topics asked during the interview (B. Bierschenk, 1974, 1977b, 1979).

The process of problem formulation is highly dependent on the researcher's information strategies and determination to become acquainted with existing research information. His plan for solving his information problem contains intentions and goal notions, plus an idea of which means can be used to achieve the goals, i.e., means-goal hierarchies. As shown in Fig. 1, his intention is to get in principle two types of information, for demarcation of concepts and about research methods.

The strategy (means) that has been designed for the first type is "Discussion of Problems" (seminars, project meetings, informal literature seminars). Problem discussion seems to be the main source of ideas. Ideas and suggestions from single persons obtained through face-to-face contact, telephone, or letter, are sought roughly once a month, which in this context refers to quite active behavior. This type of personal contact is felt to be the best source of meaningful information.

The strategy designed for the second type is to a certain extent bibliographical information-seeking and visits to international symposia, i.e., "Channels of Information" are used. Contrary to personal contacts, formal meetings do not appear to provide valuable information. The concept cluster "Research Organization" covering these has had no discriminating power either but rather a reducing effect when it is combined with the others. This further underlines the fact that their influence is regarded to be rather low.

Information strategies with respect to "Information on Research Methods" do not seem to be of any impact while "Discussion of Problems" is under way or when information for the "Demarcation of Concepts" is sought. It is sought neither by the use of different "Channels of Information" nor through "Discussion of Problems." The technical systems available for channeling information are used to a certain extent to obtain "Bibliographic References," i.e., information about information. But the actions that form the building stones in the researchers' information strategies express negative values, especially with respect to "Information on Research Methods." All the critical opinions on formal seminars and printed material indicate that the "Dissemination of Information" by the defined "Channels of Information" does not well distribute information that should have strong influence on the formulation and demarcation of ill-defined problems.

Conclusions

The ecological approach to the processing of symbolic information presented in this article constitutes an attempt to objectify originally subjective functions, namely, the abstraction of information from anamorphic text. The attempt demands careful attention for any presentation of something meaningful implies intentionality and imposes a perspective.

An information-processing model founded on the schema hypothesis leads to the abstraction of functions which seem to reflect the key relations underlying running text. The psychologically founded A a O model in combination with the experimental technique employed provides a way of making inferences to a social context in which the "facts" are empirically set up (dynamic) instead of being pre-programmed (static).

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